



The McMurdo Dry Valleys LTER

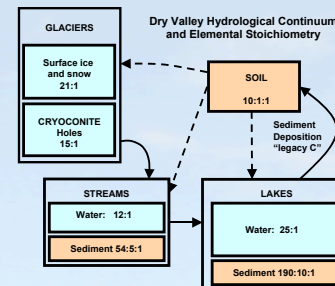
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Abstract

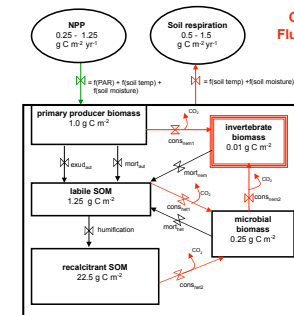
The McMurdo Dry Valleys (MCM) region is among the most extreme deserts in the world: far colder and drier than any other LTER site. The valleys contain a mosaic of perennial ice-covered lakes, ephemeral streams, glaciers and exposed soils, all of which contain viable biological communities capable of surviving the extreme climatic conditions, particularly the lack of liquid water. Subtle changes in climate have a major influence on the generation of liquid water, which produces a cascade of processes influencing the productivity, biodiversity and biogeochemistry within MCM. Our early research indicated that small changes in temperature and albedo are amplified by large non-linear changes in hydrological cycle that propagate through the ecosystem. The central hypothesis of MCM-II was that the legacy, or memory of past climate change upon the landscape, strongly overprints present ecological conditions in MCM. Results obtained in MCM-II further suggested that biodiversity and related ecosystem processes are controlled by a balance between legacies of past climates and contemporary processes. Research in MCM-III continues to investigate the MCM as a climate sensitive "end-member" ecosystem, and begins to focus on the roles of legacy and extant process on contemporary biodiversity and ecosystem structure and function. Our recent research activities, in concert with knowledge gained through MCM-II, allow us to address biodiversity issues in a more definitive manner, especially the interplay between physical dispersion and habitat suitability. We include stoichiometric and molecular diversity components in our research plan, providing a common currency to integrate all ecosystem components through documentation of landscape scale elemental transformations and genetic variation. Our recent efforts continue to focus on the integration of the biological processes within and between the glaciers, lakes, streams and terrestrial components of the ecosystem. The modeling component integrates and synthesizes our data on a landscape scale. Our primary goals are to understand both how the environment controls the diversity of organisms and how diversity itself controls the functioning of ecosystems. This is one of the hottest topics in modern ecological research and the low-diversity ecosystems of MCM lend themselves to answering these questions in a unique way.

Stoichiometry

We present a conceptual model describing transformations across dry valley landscapes facilitated by exchanges of liquid water and biotic processing of dissolved nutrients. We conclude that contemporary ecosystem stoichiometry of Antarctic Dry Valley soils, glaciers, streams and lakes results from a combination of extant biological processes superimposed on a legacy of landscape processes and previous climates. From this model we hypothesize that the elemental composition of inputs to a given system, i.e., N:P of eolian sediments, surface glacial chemistry, and/or stream discharge, constrain biological productivity, while subsequent biotic uptake and mineralization of nutrients in the water column determine the elemental ratios of "downstream" fluxes and nutrient availability. For example, spatial variation in soil nutrients and their inputs to aquatic systems contributed to the widely different nutrient ratios of stream and lake systems observed among the basins and valleys. Lake stoichiometry in particular may be strongly linked to the age of the surrounding till and weathering processes occurring in the adjacent streams and sediments. Over long time scales (i.e., glacial-interglacial), periodic lake inundation and recession redistribute C, N, and P among aquatic and terrestrial ecosystems and sustain the long term productivity of dry valley ecosystems.



Soil biogeochemistry



Glaciers

Icy habitat In the dry valleys aeolian-transported sediment and biota melt into the glacier surface forming pools of water called cryoconite holes. Cryo, meaning cold and conite meaning dust. While common to all glaciers, cryoconite holes in the dry valleys actually form in the subsurface due to a greenhouse effect. Energy balance conditions at the glacier surface are not sufficient to maintain a constantly melting surface. These holes, which cover about 7% of the ice surface of the glaciers, are typically 10 cm in diameter, 20 cm tall, and under about 30 cm of ice. They are often isolated from the atmosphere and from other holes, form small ecosystems whereby cyanobacteria photosynthesize by harvesting CO₂ from bubbles in the surrounding ice and nutrients from the aeolian sediment. This biologic process transforms the pure glacial melt waters in the holes into something more akin to an African soda lake. Hole chemistries can exhibit a pH of 11, supersaturation in CaCO₃, and in oxygen, and darken the waters to a tea color. Eventually (years?), the holes connect with a glacial hydrologic system that flushes the contents to the valley streams and lakes.

Streams

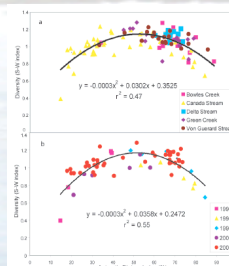
Diatom endemism and the environment of Dry Valley Streams: A molecular approach

Glacial meltwater streams support microbial mats, which consist of diatom communities present within a cyanobacterial substrate. Both widespread and endemic diatoms are present in the McMurdo Dry Valley streams. Five of these endemic diatoms are newly described species (Esposito et al submitted). A recent study shows that endemic diatoms predominate when stream flow is low and when days without flow occur more frequently (Esposito et al. 2006). These conditions correspond to a high "harshness" index on the scale developed for intermittent prairie streams by the Konza Prairie LTER. In addition, diatom diversity is highest when endemic diatoms and widespread diatoms co-occur under conditions of intermediate harshness.

The questions we will be addressing are:

- What biological components regulate diatom community responses?
- Do silica transport genes reflect the speciation process and can they be used as markers indicating previous flow conditions?
- Are endemics a separate lineage, or has speciation occurred multiple times among the diatoms?

Answering these questions will further our understanding of diatom biology and stream ecosystem processes in the Antarctic, and will be available to the public via the Freshwater Diatoms online database.



a. Shannon-Wiener diversity index as a function of ADI, measured as the relative abundance of Antarctic diatoms for several Dry Valley streams and Canada Stream over several years. b. Newly described diatoms, which can be found on the Antarctic Diatom Website: <http://huey.colorado.edu/diatoms/about/index.php>

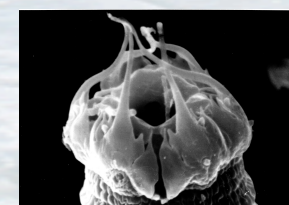
Nutrient Fate and Transport in Dry Valley Streams

Nitrogen and phosphorus limit biologic activity in many systems, but are prevalent in the McMurdo Dry Valleys. Glacial meltwater leaches these nutrients from the unconsolidated sediments, resulting in high nutrient concentrations in streams and high yields to the closed-basin lakes. In streams with favorable environmental conditions, nutrient-rich water leads to growth of algae and bacteria. Analysis of the long term monitoring data shows that streams with abundant algae reduce nutrient loads to the lakes (McKnight, 2004). A nutrient enrichment tracer experiment in a stream containing algae showed that uptake and denitrification were responsible for the majority of nitrate loss in algae-rich streams. 7 to 16 % of the nitrate loss occurred in the hyporheic zone, suggesting that bacteria are active in the subsurface. While shallow permafrost prevents regional groundwater movement, hyporheic exchange does occur in the area proximal to the streams. Recent research is delving further into water storage and its effects on stream nutrient transport and uptake by addressing the following questions:

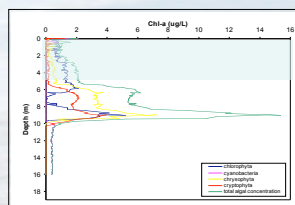
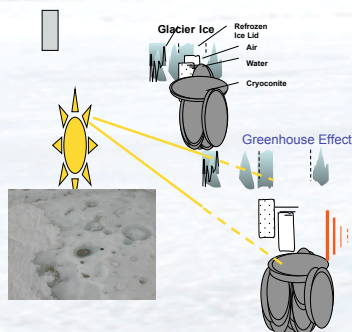
- What are the rates and processes of nitrogen use associated with subsurface biologic activity?
- How do stream braids and plays affect subsurface flow paths and residence times?
- How great is the effect of variable water temperature on subsurface hydraulic conductivity?

Soil biodiversity

Fig. 1. Anterior view of *Scottinema lindsayae*, the dominant nematode species in the McMurdo Dry Valleys.



Diana Wall's team, collaborating with co-determining the role and feedbacks of biodiversity to ecosystem function.



Lakes

Phytoplankton diversity

As the key phototrophic organisms in the MCM ecosystem, phytoplankton have an essential role as primary producers of new carbon. Phytoplankton diversity profiles were obtained during the 2004 and 2005 austral spring and summer in four Taylor Valley lakes (Fryxell, Hoare, East and West lobe Bonney) and Lake Vanda in the Wright Valley. A subsurface spectrophuorometer which differentiates four major groups of